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(54) **Creep resistant gamma titanium aluminide**

(57) A creep resistant gamma or near gamma titanium aluminide includes carbon in the composition in an amount of at least about 0.03 weight % effective to

increase high temperature creep resistance as compared to similar materials devoid of carbon.

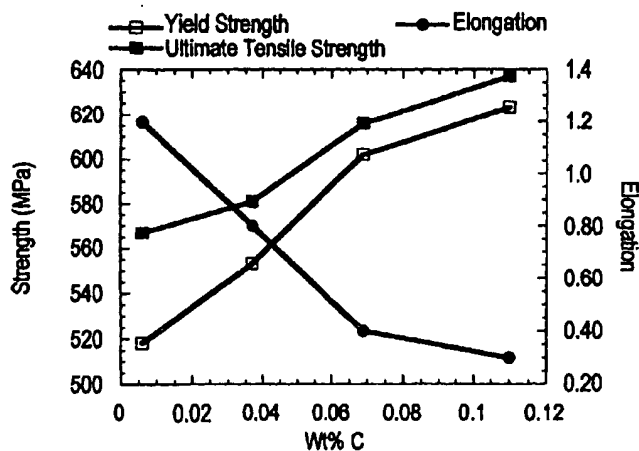


FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to titanium aluminum alloys and, more particularly, to gamma and near gamma titanium aluminides having dramatically improved creep resistance at elevated temperature.

BACKGROUND OF THE INVENTION

[0002] The ongoing search for increased aircraft engine performance has prompted materials science engineers to investigate intermetallic compounds as potential replacement materials for nickel and cobalt based superalloys currently in widespread use for gas turbine engine hardware. Of particular interest over the past decade have been gamma and near gamma titanium aluminides as a result of their low density and relatively high modulus and strength at elevated temperatures. For example, Larsen U.S. Patent 4 294 615 describes a titanium aluminide having a composition selected within broader prior titanium aluminide compositions to provide a combination of high temperature creep strength together with moderate room temperature ductility. The patent investigated numerous titanium aluminide compositions set forth in Table 2 thereof and discloses an optimized alloy composition wherein the aluminum content is limited to 34-36 weight % and wherein vanadium and carbon can be added in amounts of 0.1 to 4 weight % and 0.1 weight %, respectively. The '615 patent identifies V as an alloying element for improving low temperature ductility and Nb, Bi, and C as alloying elements for improving creep rupture resistance. If improved creep rupture life is desired, the alloy is forged and annealed at 1100 to 1200 degrees C followed by aging at 815 to 950 degrees C.

[0003] Moreover, further improvements in mechanical properties of the gamma and near gamma titanium aluminum compositions have been achieved by distributing strengthening dispersoids, such as for example only, TiB₂ dispersoids, throughout the microstructure. For example, Larsen US Patent 5 248 620 describes investment casting of titanium aluminide compositions comprising, in atomic %, about 40% to about 52% Ti and about 44% to about 52% Al and one or more alloying elements selected from Cr, C, Ga, Mo, Mn, Nb, Ni, Si, Ta, V and W each in an amount of 0.05% to about 8% along with at least about 0.5 volume % boride dispersoids present in the microstructure.

[0004] An object of the present invention is to provide a gamma and near gamma titanium aluminide with carbon content controlled in a range discovered to unexpectedly and significantly increase creep resistance at elevated temperature.

SUMMARY OF THE INVENTION

[0005] The present invention provides in one embodiment a gamma and near gamma titanium aluminide including a carbon concentration controlled in an amount of at least about 0.03 weight % C effective to surprisingly and unexpectedly increase high temperature creep resistance by approximately 10 times as compared to similar materials devoid of carbon.

[0006] The present invention provides in another embodiment a titanium aluminide composition comprising titanium in the range of about 53 to about 64 weight % and aluminum in the range of about 29.5 to about 38 weight % wherein carbon is included and controlled in the composition in an amount of about 0.03 weight % to about 0.33 weight % to increase high temperature creep resistance.

[0007] A preferred titanium aluminide composition in accordance with the invention consists essentially of, in weight %, about 60.0% to about 63.5% Ti, about 29.5% to about 33.0% Al alloyed with one or more elements selected from Cr, Ga, Mo, Mn, Nb, Ni, Si, Zr, Ta, V and W each in amount of at least about 0.1 weight %, carbon controlled as described above and including strengthening dispersoids present in an amount of at least about 0.5 volume %.

[0008] A more preferred titanium aluminide composition in accordance with the invention consists essentially of, in weight %, about 31.5% to about 32.5% Al, about 4.0% to about 5.5% Nb, about 1.5% to about 3.0% Mn, about 0.2% to about 0.4% B, and about 0.04% to about 0.1% C and balance essentially Ti. Another more preferred titanium aluminide composition in accordance with the invention consists essentially of, in weight %, about 29.8% to about 31.2% Al, about 4.0% to about 5.2% Nb, about 1.5% to about 3.0% Mn, about 0.25% to about 0.37% B, and about 0.04% to about 0.1% C and balance essentially Ti. The composition can be investment cast, permanent mold cast, and vacuum die cast and heat treated alloy to provide a microstructure comprising predominantly gamma (TiAl) phase and a minor amount (e.g about 5 to about 20 volume %) of alpha-2 (Ti₃Al) phase. The aforementioned objects and advantages of the invention will become more readily apparent from the following detailed description taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Figure 1 is a graph of carbon content in weight % versus tensile strength, yield strength and elongation at room temperature of illustrative dispersion strengthened titanium aluminide compositions.

Figure 2 is a graph of carbon content in weight % versus tensile strength, yield strength, and elongation at 650 degrees C of the carbon-modified dis-

persion strengthened titanium aluminide alloy compositions of Figure 1.

Figure 3 is graph of carbon content in weight % versus time to 0.5% creep at different temperatures and stresses as designated in the legend box of the carbon-modified dispersion strengthened titanium aluminide alloy compositions of Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

[0010] The present invention provides in one embodiment a titanium aluminide composition comprising titanium in the range of about 53 to about 64 weight % and aluminum in the range of about 29.5 to about 38 weight % wherein carbon is included and controlled in the alloy composition in an amount of at least about 0.03 weight % C, preferably about 0.04 to about 0.33 weight % C, and more preferably about 0.04 to about 0.1 weight % C, to increase high temperature creep resistance by approximately 10 times as compared to similar composition devoid of carbon.

[0011] A preferred titanium aluminide composition in accordance with the invention consists essentially of, in weight %, about 60.0% to about 63.5% Ti, about 29.5% to about 33.0% Al alloyed with one or more alloying elements selected from Cr, Ga, Mo, Mn, Nb, Ni, Si, Zr, Ta, V and W each in amount of at least about 0.1 weight %, about 0.03% to 0.33% C, and including strengthening dispersoids present in an amount of at least about 0.5 volume %.

[0012] For purposes of illustrating and not limiting the invention, carbon-modified titanium aluminide alloy base compositions comprising 47 atomic % Al, 2 atomic % Mn, 2 atomic % Nb, and balance Ti with 0.8 volume % TiB₂ dispersoids was prepared as cylindrical specimen bars (dimensions of 5/8 inch diameter and length of 8 inches) by vacuum arc melting a master heat of the alloy composition that included 0.8 volume % TiB₂ dispersoids pursuant to US Patents 5 284 620 and 5 429 796, the teachings of which are incorporated herein by reference to this end. Other melting techniques such as vacuum induction melting, induction skull melting, and plasma arc melting also can be used to melt the master heat. The dispersoids can be provided in the master heat by adding an appropriate amount of a 95 weight % Al-5 weight % B alloy to the heat.

[0013] The master heat was melted at less than 20 microns atmosphere and then cast at a superheat of about 50 degrees F into an investment mold. The carbon content of the specimen bars was controlled by melt addition of premeasured Al₄C₃ to provide aim carbon concentrations of 0%, 0.04%, 0.07% and 0.11% (weight %) of the base alloy compositions for tensile and creep testing. The composition having nominal carbon content of 0.006 weight % C was considered and designated the 47XD baseline composition. Table 1 below sets forth the titanium aluminide compositions studied with the actual carbon concentrations set forth.

Table 1

Heat Number	Alloy	Actual Carbon
1	47XDBaseline	0.006 wt. %
2	47XD+0.04C	0.037 wt. %
3	47XD+0.07C	0.065 wt. %
4	47XD+0.11C	0.110 wt. %

[0014] The as-cast microstructure of the specimen bars having the aforementioned carbon contents were similar and comprised a lamellar structure containing laths of gamma phase and alpha-2 phase present as a minor phase. Since carbon solubility in both the alpha-2 phase and gamma phase is fairly low (e.g. less than 0.1 atomic %), the carbon forms fine (less than 1 micron particle diameter) carbide precipitates throughout the as-cast microstructure primarily at the grain boundaries and lamellar interfaces.

[0015] Such carbide precipitates have been found to increase room and elevated temperature strength and creep resistance of the alloy in the as-hot isostatically pressed (HIP'ed) condition and as-heat treated.

[0016] For example, test specimens for tensile testing and creep testing were machined from cast and HIP'ed specimen bars. The tensile and creep test specimens were machined and tested in accordance with ASTM test standard E8.

[0017] Before machining, the cast test specimens were hot isostatically pressed at 2300 degrees F and argon pressure of 20 ksi for 4 hours. Then, the test specimens were heat treated at 1800 degrees F for 50 hours in an argon atmosphere and allowed to furnace cool to ambient by furnace power shut-off.

[0018] The heat treated microstructure of the test specimens having the aforementioned carbon contents were similar with both lamellar and equiaxed grains and comprised predominantly gamma phase (TiAl) and a minor amount (e.g. 5 volume %) of alpha-2 phase.

[0019] Heat treated specimens were subjected to room temperature (RT) and elevated temperature (650 degrees C) tensile testing in accordance with ASTM test standard E8. Table 2 below and Figures 1 and 2 illustrate the measured results of the compositions of Table 1. In Table 2, 0.2% YS is 0.2% yield strength, UTS is ultimate tensile strength, and EL is elongation.

Table 2

C Addition	RT Tensile MPa(Ksi)		
	0.2% YS	UTS	EL
0.006	518(74)	567(81)	1.2
0.037	553(79)	581(83)	0.8
0.069	605(86)	618(88)	0.4
0.110	624(89)	638(91)	0.3
C Addition	650 Degrees C Tensile MPa(Ksi)		
	0.2% YS	UTS	EL
0.006	392(56)	560(80)	3.6
0.037	471(67)	662(95)	3.6
0.069	479(68)	622(89)	2.9

[0020] In the range of carbon additions tested, the tensile strength increased with carbon content from 74 ksi for the 47XD baseline alloy up to 89 ksi for the 0.11 weight % C 47XD alloy. A similar increase in strength was seen in the 650 degrees C tensile tests. Room temperature ductility decreased with carbon content from 1.2% elongation for the 47XD baseline alloy to 0.3% elongation for the 0.11 weight % C XD47 alloy. The room temperature ductility of the 47XD baseline alloy typically is in the range of 1.2 to 1.4% elongation.

[0021] Heat treated specimens were subjected to steady state creep testing in accordance with ASTM test standard E8 at 649 degrees C and test stress of 276 MPa and at 760 degrees C and 815 degrees C and test stress of 138 MPa, Figure 3. The time to reach 0.5% elongation was measured, Figure 3.

[0022] The average time to reach 0.5% elongation for tensile creep specimens is shown in Figure 3 for the specimens having the aforementioned carbon concentrations.

[0023] The addition of carbon improved the creep resistance of the alloys tested as measured in time to 0.5% elongation at a given temperature. Rather than being a simple linear behavior over the range of carbon additions as was seen in the tensile strength behavior, the creep resistance appears to reach a maximum between 0.6 to 0.8 weight % C and then decreases, which behavior is unexpected. At the maximum, the carbon addition increased the time to 0.5% elongation by well over 10 times (an order of magnitude) as compared to the 47XD baseline alloy, Figure 3.

[0024] The titanium aluminide compositions of the invention can be produced by traditional ingot production methods, including, but not limited to, VAR (vacuum arc remelting) or PAM (plasma arc melting). Components can be produced from these alloys via a variety of methods including traditional cast, wrought, or powder metallurgy methods, with the preferred methods includ-

ing investment casting, permanent mold casting, and vacuum die casting.

[0025] Although the present invention has been described in detail hereabove with respect to certain embodiments for purposes of illustration, the invention is not so limited and modifications and changes can be made therein within the scope of the appended claims.

Claims

1. Titanium aluminide comprising titanium in the range of about 53 to about 64 weight % and aluminum in the range of about 29.5 to about 38 weight % wherein carbon is included and controlled in the alloy composition in an amount of at least about 0.03 weight % effective to increase high temperature creep resistance as compared to similar alloy devoid of carbon.
2. Titanium aluminide consisting essentially of, in weight %, about 60% to about 63.5 % Ti, about 29.5% to about 33.0% Al alloyed with one or more alloying elements selected from Cr, Ga, Mo, Mn, Nb, Ni, Si, Zr, Ta, V and W each in amount of at least 0.1 weight % and strengthening dispersoids present in an amount of at least about 0.5 volume % wherein carbon is included and controlled in the composition in an amount of about 0.04 to about 0.33 weight % effective to increase high temperature creep resistance as compared to similar alloy devoid of carbon.
3. Titanium aluminide consisting essentially of, in weight %, about 31.5% to about 32.5% Al, about 4.0% to about 5.5% Nb, about 1.5% to about 3.0% Mn, about 0.2% to about 0.4% B, and about 0.04% to about 0.10% C and balance essentially Ti.
4. Titanium aluminide consisting essentially of, in weight %, about 29.8% to about 31.2% Al, about 4.0% to about 5.2% Nb, about 1.5% to about 3.0% Mn, about 0.25% to about 0.37% B, and about 0.04% to about 0.10% C and balance essentially Ti.

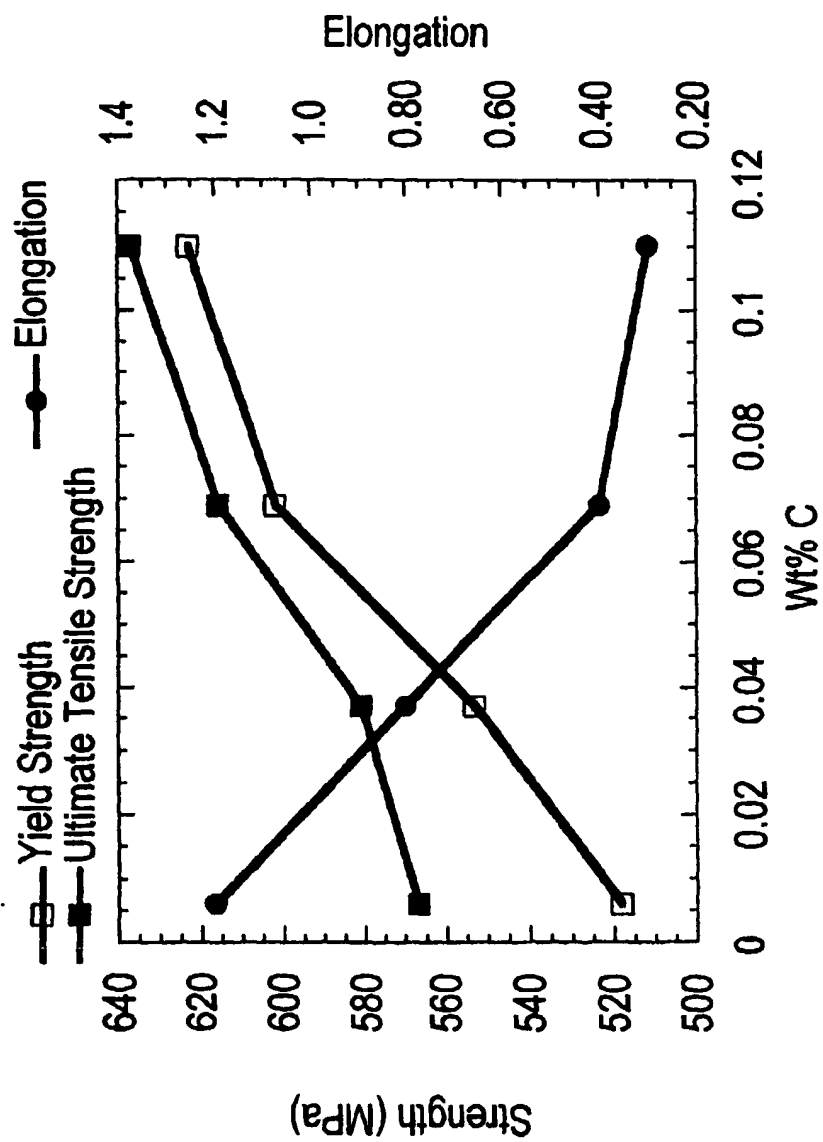


FIG. 1

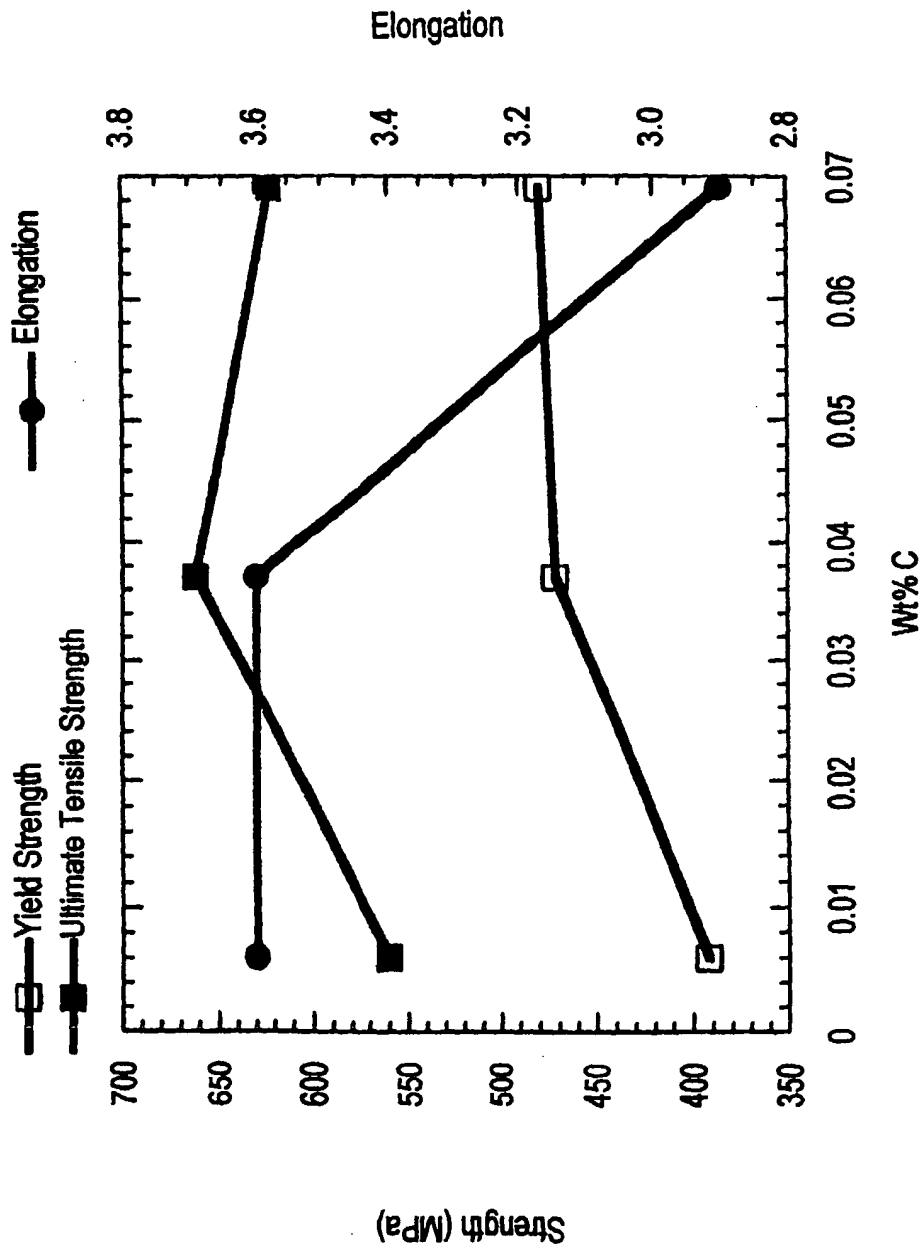
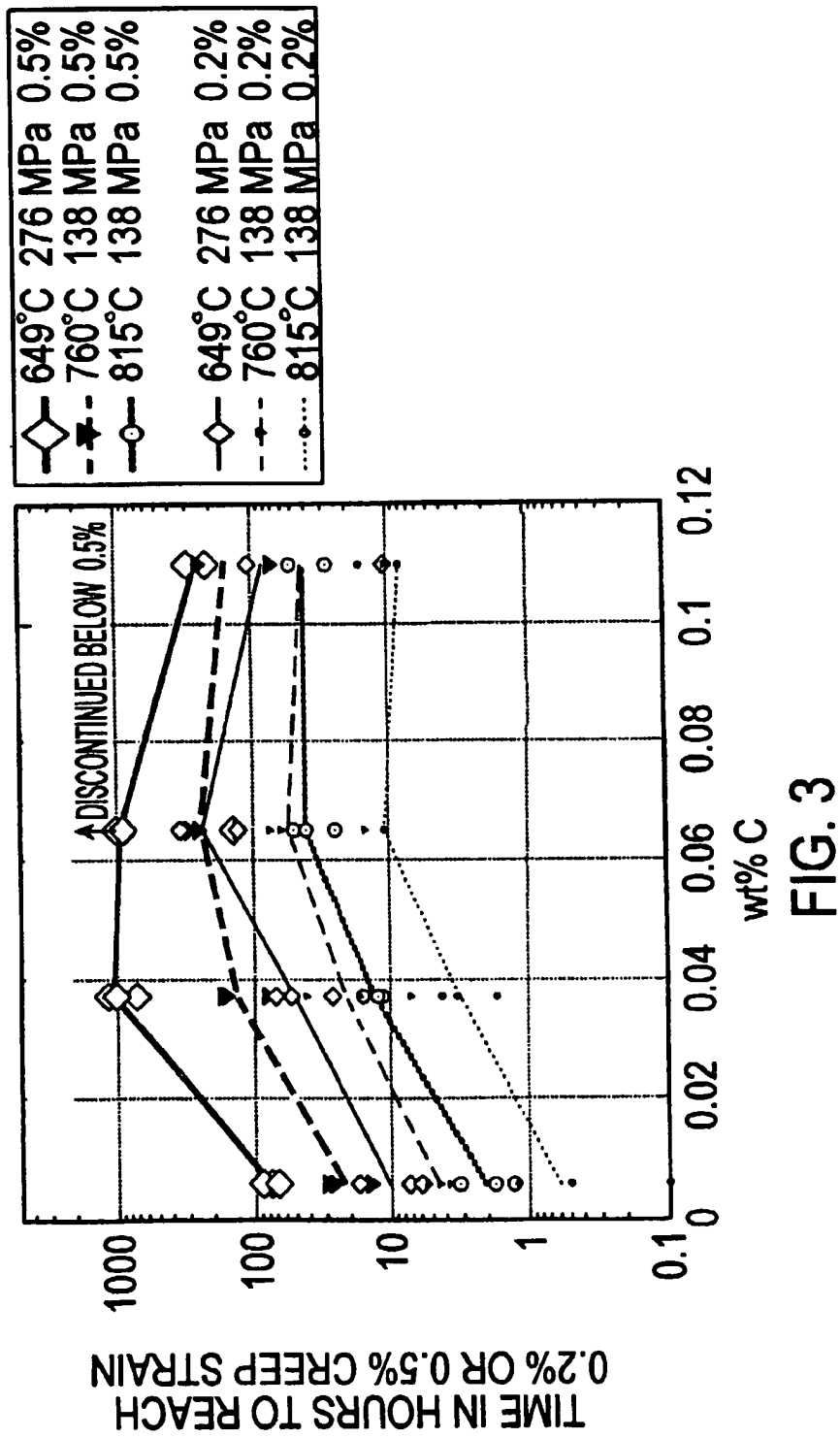


FIG. 2





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EUROPEAN SEARCH REPORT

Application Number
EP 00 10 9140

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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 26 July 2000	Examiner Gregg, N
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

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